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DEVICE FOR CONVERTING THE HEAT DISSIPATED INTO THE EXHAUST GASES OF AN INTERNAL COMBUSTION ENGINE INTO ELECTRICITY

[Dispositif pour la transformation en éléctricité de la chaleur dissipée dans les gaz d'échappement d'un moteur à combustion interne]

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d’échappement d’un moteur à combustion

interne

The object of the present invention is a device for converting the heat contained in the exhaust gases /1[*] of an internal combustion engine into electricity, in particular but not exclusively in motor vehicles, with the electricity thus produced being immediately usable in the vehicle or stored in the battery thereof.

It is known that internal combustion engines, whether [powered by] gasoline, diesel fuel or gas, use only a small portion of the energy contained in the fuel in order to convert it into mechanical energy, the entire remainder of this energy being lost in the form of heat, in particular via the exhaust gases.

The purpose of the invention is to recover the greatest possible portion of the heat energy lost through exhaust by converting it into electrical energy capable of being used to operate the engine itself and for electrical accessories mounted on the electric circuits of motor vehicles.

According to the invention, the device includes a thermoelectric converter consisting of a series of thermoelements electrically connected to one another and to the electrical circuit of the vehicle, and arranged between an enclosure which communicates with an exhaust pipe for the burned gases and with the cooling fluid circuit of the engine, forming a cold source, with means being provided to ensure the conduction of heat between the exhaust gases and the cooling circuit, via the thermoelements, so as to create an electric current therein, while the gases that have passed through the enclosure are discharged towards the muffler.

The thermoelectric converter thus produced from a hot source consisting of the exhaust gases and from a cold source consisting of the cooling fluid circuit of the engine, thus produces electrical current the voltage of which depends, in particular, on the difference in temperature between the hot and cold /2 sources. The device thus produced can therefore very advantageously replace the direct-current generators or alternators which are associated with internal combustion engines and which

[*] [Numbers in right margin indicate pagination of the original text.]

conventionally supply the electrical energy required by the engine and electrical accessories of the vehicle.

Among other advantages, the invention thus saves energy by recovering calories that have until now been lost, and makes it possible to replace rotating machines (direct-current generators or alternators) with static systems. This results in increased reliability and noiseless running.

According to one embodiment of the invention, the enclosure of the converter is equipped with interior heat exchange fins facilitating transfer of heat from the gases to the thermoelements, while an electrical insulator is interposed between the enclosure and the latter, on the one hand, and between the cooling fluid circuit and said thermoelements, on the other hand.

According to another embodiment of the invention, wherein the cooling fluid is water, which forms the cold source of the converter, the invention provides for this cold source to consist of radiators placed in contact with the thermoelements, through which water flows and which are connected at the ends thereof to the cooling circuit of the vehicle.

According to another characteristic, the invention provides for the thermoelements to be connected to a voltage regulator which converts the voltage supplied by the thermoelements into direct current voltage capable of being used by the electrical equipment of the vehicle.

The thermoelements can be doped P or N-type homogenous semiconductor rods made, for example, of lead telluride, or [else] composite [and] made, for example, from two end-to-end elements made of /3
lead telluride and bismuth telluride.

The characteristics of the thermoelectric converter thus made depend in particular on the number and nature of the thermoelements positioned electrically in series and thermally in parallel.

Other features and advantages of the invention will become apparent over the course of the following description.

In the appended drawings, several possible embodiments of the device according to the invention have been shown for non-limiting illustrative purposes.

Figure 1 is an elevation showing the operating principle of a thermoelectric converter.

Figure 2 is a simplified schematic showing the electricity-producing device according to the invention, which is connected to the cooling circuit of an internal combustion engine.

Figure 3 is an axial section of the thermoelectric converter forming part of the device diagrammed in figure 2.

Figure 4 is a cross-sectional view along IV-IV of figure 3.

Figure 5 is an elevation showing an alternative embodiment of a thermoelement of the converter according to the invention.

Figure 6 is a half sectional, half longitudinal elevation view of a second alternative embodiment of the thermoelectric converter in accordance with the invention.

Figure 1 is a schematic representation of the principle of a thermoelectric converter: a thermocouple comprises two elements 1, 2, with element 1, for example, being of the P-type, with a positive Seebeck coefficient, while the other element 2 is of the N-type, with a negative Seebeck coefficient. These /4 elements consist of semiconductor rods, which are appropriately chosen in consideration of the thermoelectric characteristics thereof and of the anticipated working temperature range. The two elements 1 and 2 are joined by an electrical connecting strip 3, and each element 1, 2 is connected to the adjoining [thermo]couple (not shown) by a connecting strip 4.

The converter comprises a cold source Sf and a hot source Sc, which are electrically insulated from the strips 3 and 4 by heat-conductive insulating layers 5.

The heat flux derived from the hot source Sc passes through elements 1, 2 towards the cold source Sf, thereby creating a temperature gradient along each rod 1, 2, which results in the appearance of an

electromotive force in the [thermo]couple, the magnitude of which is related to the difference in temperature. By positioning a certain number of thermocouples in series and thermally in parallel, a direct-current generator is thereby obtained in a known manner per se.

The invention provides for the production of electricity in a motor vehicle from a hot source consisting of the burned gases flowing in the exhaust pipe towards the muffler, and from a cold source consisting of the cooling fluid circuit of the vehicle (water or air). A first embodiment of this device will be described with reference to Figures 2 to 4.

Figure 2 is a schematic representation of the cooling circuit and exhaust gases of the internal combustion engine of a motor vehicle.

This circuit is water-cooled and, in a known manner, comprises a first pipeline 6 equipped with a water pump 7, wherein hot water coming from the engine circulates, a radiator 8 into which the pipeline /5
6 opens out, a second pipeline 9, which is connected to the radiator 8 and which recycles the cooled water to the engine of the vehicle. The exhaust pipe has been represented schematically by the pipe 11 [drawn] in dotted and dashed lines, which opens out into the muffler, not shown.

The device according to the invention includes a thermoelectric converter 12 interposed between the exhaust pipe 11 and the muffler, the hot source of which consists of an enclosure opening out at the ends thereof into the exhaust pipe 11 and in the direction of the muffler, while the cold source of same consists of water radiators 13. The latter communicate, on the one hand, with a secondary radiator 14, which is connected to the outlet 15 of the primary radiator 8, and on the other hand, with the intake pipeline 6 via pipe 16.

The path followed by the cooling water has been shown by the arrows drawn in Figure 2.

The converter 12 includes a series of thermoelements 17 (Figures 3 and 4), which are connected together electrically via connecting strips 18 and to the electrical circuit of the vehicle via connections

19. These rows of elements 17 are arranged between an enclosure 21 which, at the inlet thereof, communicates with the exhaust pipe 11, and which, at the outlet 22 thereof, [communicates] with a manifold 23 hooked up to the muffler (not shown) for the burned gases; the outside radiators 13 are hooked up to the water cooling circuit of the vehicle 15, 16.

The direction of water flow inside the radiators 13 is indicated by the arrows F.

The enclosure which, in the example shown, is of an overall parallelepiped shape, is equipped with an assembly of interior heat exchange fins 24 the function of which is to facilitate the transfer of heat /6
from the burned gases to the thermoelements 17. An electrical insulator 25/10 is interposed between the enclosure 21 and the rods 17, on the one hand, and between the radiators 13 of the cold source and the rods 17, on the other hand. This electrical insulator can be alumina, for example, which, in fact, has the advantage of being a good heat conductor.

Connections 19 are connected to a voltage regulator 26 that converts the direct-current voltage coming from the thermoelements 17 into a stabilized direct-current voltage, which can then be either stored in the storage battery of the vehicle, or else used directly for operating the engine and/or for powering the electrical accessories of the vehicle.

The ends of the thermoelements 17 are advantageously coated with a layer of iron, which is deposited, for example, by cathode sputtering [and] interposed between these ends and the connecting strips 18. The latter are brazed onto the layer of iron.

As a matter of fact, the majority of metal ions contaminate the thermoelements by migrating to the interior thereof, thereby degrading their thermoelectric characteristics. Such being the case, iron behaves neutrally with respect to these materials and does not damage them.

The thermoelements 17 can be homogeneous or composite semiconductor rods. For non-limiting illustrative purposes, if they are homogeneous, they can be made of P-type lead telluride doped with 1%

Na, and of N-type [doped] with 0.03% PbI_2. If these rods are composite, they can be made, for example, of two elements 17a, 17b (alternative of Figure 5), placed end-to-end, [and] made of lead telluride /7
PbTe and bismuth telluride Bi_2Te_3, respectively. Since, for temperatures lower than 200°C, bismuth telluride has a markedly higher performance than that of lead telluride, rods consisting of these two materials can be made such that, at thermal equilibrium, with the hot junction being at 500°C, and the cold junction at 100°C, bonding between the two rods 17a and 17b occurs at 200°C.

The tubes 11a, 11b, 11c, 11d (Figure 4) forming the exhaust pipe 11 are polished externally and internally, and covered externally with a heat-insulation material 28 (Figure 3). These arrangements, combined with the fact that the tubes 11a-11d are also preferably disconnected from the cylinder head of the engine, make it possible to significantly limit heat losses from the burned gases prior to the entry thereof into the enclosure 21.

The rows of thermoelements 17 arranged on both faces of the enclosure 21 can vary in number, depending on the desired electrical voltage, while also taking into account the temperature of the hot source (approximately 500°C), formed by the exhaust gases, and [that] of the cold source consisting of the water inside the radiators 13 (approximately 80 to 100°C). As an indicative example, it is thus possible to provide for 300 [thermo]couples consisting, on the one hand, of lead telluride rods 17 measuring 10 mm long and having a cross-sectional area of 12 x 12, of the P-type doped with 1% sodium, and on the other hand, N-type rods doped with 0.03% PbI_2. It is established that an electromotive force E = 56.4 volts is obtained at the terminals of the converter, for an internal resistance R = 1.5 ohms.

Under these conditions, the power available on the exterior of the converter is 530 watts. At start-up, at the moment the engine warms up, the voltage varies from zero to this maximum voltage of 56.4 volts. /8

The voltage regulator 26 can be a DC-to-DC converter unit which chops this voltage and then converts it into an alternating voltage of 15 volts, which is rectified. If the output of the converter 26 is 75%, 400 watts are thus available at the circuit outlet.

It is appropriate to note that, in order to ensure proper thermal contact, it is necessary to keep the thermoelements 17 under pressure between the hot source (burned gases passing through the enclosure 21) and the cold source (radiators 13).

Since the central hot source is stationary, the radiators 13 can be mounted floatably and pressed against the thermoelements 17 by means of springs (not shown), which are placed beneath the fastening screw heads.

The implementation of a thermoelectric converter such as the one just described, on a motor vehicle, in place of the conventional dynamic electric generators (direct-current generators, alternators) mounted on internal combustion engines, has significant and multiple advantages.

First of all, as already indicated, the implementation of a converter such as this enables energy savings, by recovering the calories contained in the exhaust gases.

Since this device is static, and not dynamic, it does not include any rotating parts, and for this reason has better reliability and is completely noise-free. It enables replacement of engine accessories previously driven by bulky and unreliable systems of pulleys and belts. The manufacture of the engines is correspondingly simplified.

It becomes possible to increase the number and power of the electrical accessories of vehicles (air conditioning, power assistance and various automatic controls) without increasing fuel consumption.

Finally, exhaust pipes can be simplified and thus rendered less costly, due to the fact that the gases /9
derived from the converter according to the invention contain less energy than the gases normally derived from the exhaust pipe.

In the alternative of Figure 6, the converter 29 comprises two banks 31, 32 of thermoelements 33, which are thermally insulated by a partition 34 represented by dotted and dashed lines. The first portion 31 through which the hottest gases pass has a high temperature, while the following portion 32 is less hot, it thereby being possible for several banks of thermally separated thermoelements to be provided along and around the enclosure 21. The equilibrium temperature of these successive banks 31, 32... may be increasingly lower up until the last one. Under these conditions, each bank can be equipped with composite thermoelements chosen so as to be suited to the equilibrium temperature of the bank in question.

The invention is not limited to the embodiments described and can comprise numerous alternative embodiments. It is thus possible, of course, to increase the number and size of the thermoelectric elements, within the limits of available volume and power. Another alternative derived from that of Figure 6 consists in producing a heat exchange enclosure which is sufficiently long for a temperature gradient to be established there, between the inlet and the outlet, where the gases have already lost a large portion of the energy thereof. Thermoelements adapted to the local temperature are therefore arranged along this exchanger.

In the above example, the device was described in relation to a water-cooled circuit, however it is possible to produce the device comprising the converter according to the invention, in the case of air /10
cooling. The cold source ventilated by the air is then equipped with cooling fins in thermal contact with the thermoelements and electrically insulated therefrom. In the case where cooling is carried out with water, the radiators 13 can be replaced by an annular radiator surrounding a rotating heat exchange enclosure, around which the thermoelements are arranged. It is also noted that the secondary radiator 14 makes it possible to lower the temperature of the cold source.

Good electrical continuity between the thermoelements and the connecting strips can be obtained by any other appropriate means other than aforementioned welding, e.g., by pressing the strips onto the thermoelements.

It would likewise be possible to provide for thermoelements which are arranged in series, and which, as they heat up, would be divided by relays into parallel-connected banks. At each predetermined voltage level, relays thereby shift the successive banks and sub-banks of thermoelements from the series connection to the parallel connection.

A device such as this makes it possible to limit the voltage at the regulator input to an appropriate value.

Claims /11

1. Device for converting the heat contained in the exhaust gases of an internal combustion engine into electricity, this electricity being immediately usable in the vehicle or stored in the battery thereof, characterized in that it includes a thermoelectric converter (12) consisting of a series of thermoelements (17, 17a, 17b) electrically connected to one another and to the electrical circuit of the vehicle, and arranged between an enclosure (21) which communicates with an exhaust pipe (11) for the burned gases and with the cooling fluid circuit (16) of the engine, forming a cold source, with means being provided to ensure the conduction of heat between the exhaust gases and the cooling circuit (16), via the thermoelements (17, 17a, 17b), so as to create an electric current therein, while the gases that have passed through the enclosure (21) are discharged towards the muffler.

2. Device according to Claim 1, characterized in that the enclosure (21) is equipped with interior heat exchange fins (24) facilitating transfer of heat from the gases to the thermoelements (17), while an

electrical insulator (10) is interposed between the enclosure (21) and the latter, on the one hand, and between the cooling fluid circuit and said thermoelements (17), on the other hand.

3. Device according to one of Claims 1 and 2, wherein the cooling fluid is water, which forms the cold source of the converter, characterized in that this cold source consists of radiators (13) placed in contact with the thermoelements (17), through which water flows and which are connected at the ends thereof to a pipe (16) of the cooling circuit of the vehicle.

4. Device according to one of Claims 1 to 3, characterized in that the thermoelements (17), through /12
which a direct current flows during exhaust of the gases, are connected to a voltage regulator (26) which converts the voltage received into voltage usable by the electrical accessories and equipment of the vehicle.

5. Device according to one of Claims 1 to 4, characterized in that the thermoelements are homogeneous metal rods (17), which are made, for example, of doped P-or N-type lead telluride, or composite, [and] made, for example, of two elements (17a, 17b) [placed] end-to-end, [and] made of lead telluride and bismuth telluride.

6. Device according to one of Claims 1 to 5, characterized in that the ends of the thermoelements (17, 17a, 17b) are coated with a layer of iron, which is interposed between these ends and electrical connecting strips (18) welded thereon, in order to prevent contamination of the thermoelements (17, 17a, 17b) by the metal ions of the strips (18).

7. Device according to one of Claims 1 to 6, characterized in that the tubes (11a-11d) forming the exhaust pipe (11) are polished externally and internally and covered with a heat-insulation material (28), in order to limit losses, these tubes (11a-11d) furthermore being preferably disconnected from the cylinder head of the engine.

8. Device according to one of Claims 1, 2 and 4 to 7, wherein the engine cooling fluid is air, characterized in that the cold source ventilated by air is equipped with cooling fins in thermal contact with the thermoelements and electrically insulated therefrom.

9. Device according to one of Claims 1 to 8, characterized in that the converter comprises at least /13
two banks (31, 32) of thermally insulated thermoelements (33), each bank (31, 32) consisting of composite thermoelements chosen so as to be suited to the equilibrium temperature of said bank.

Fig: 1

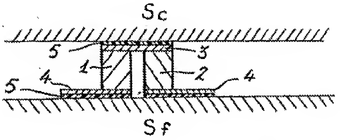


Fig: 2

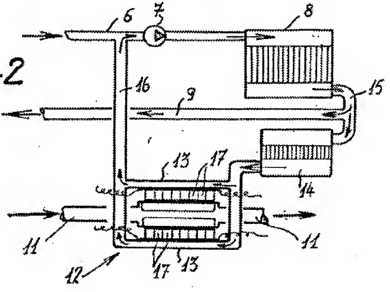
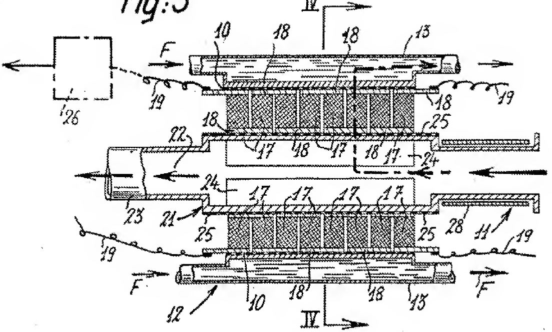


Fig:3



IV
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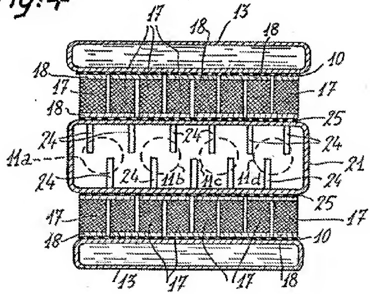
IV

Fig:4



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11a
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Fig:5

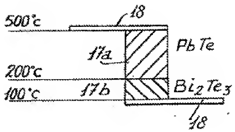
18
500°c
PbTe
17a
200°c
100°c
17b
Bi2Te3
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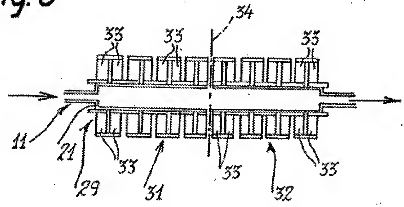
Fig:6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